Report of the 29th Met Office Scientific Advisory Committee Meeting (21-23rd January 2025)

The 29th Met Office Scientific Advisory Committee (MOSAC) meeting was held in person the 21-23rd January 2025, Exeter, UK.

The MOSAC conducted a comprehensive evaluation of selected scientific research initiatives at the Met Office, with a focus on advancements in weather, climate, and oceanographic services. This review aimed to assess the relevance and quality of the R&D efforts, as well as their effectiveness in leveraging partnerships to enhance the Met Office's services and the insights provided to its sponsors.

The Met Office is currently undergoing significant changes, both internally and externally. Its future will crucially hinge on the important decisions that will be made and implemented over the next one to two years.

The assessment by MOSAC revealed that the Met Office's research and development activities are of exceptional quality and align well with the needs of its sponsors and the broader global meteorological and climate science communities. The review highlighted numerous strengths, showcasing the dedication and innovation present within the Met Office. Moreover, it pinpointed areas needing enhancement, providing valuable recommendations to further strengthen the scientific foundation of the Met Office's services.

We outline the key points of these recommendations here. For detailed information and specific references, such as "FC-R1," please consult the comprehensive report available in the Annex.

We thank MOSAC for their time and their insightful comments during the meeting and in this report. Responses to the questions and comments are provided in red.

Science and Technology

Embracing AI/ML and Data

The Met Office is deploying new supercomputers (Gen1a, b, and eventually Gen2), a monumental task that deserves recognition and moving to the cloud. These advancements allow for strategic initiatives like parallel suite releases and enhanced climate modelling.

Additionally, AI and machine learning (AI/ML) are making their mark in meteorology and climate studies. To focus more on AI/ML, the Met Office has prioritized resources, though this affects staff and community contributions. Maintaining strong partnerships is essential. The AI4NWP and AI4CLIMATE programs show promising results, but a clear AI/ML and data strategy is needed (STO-R1, AI-R1 and SDE-R3).

The Met Office should develop a roadmap to determine where they aim to lead or follow, affecting resources and partnerships. MOSAC encourages leveraging the Met Office's expertise in physics and hybrid approaches. Strategic personnel planning and resource alignment are vital. Strengthening data management coherence is also recommended, considering AI/ML developments (STO-R2).

MOSAC supports staffing increases for AI efforts but seeks clarity on filling research observation gaps, especially given the financial climate. Collaboration with universities and research partners

may be necessary. A realistic cost strategy for commissioning and mapping research partner dependencies is recommended (STO-R3).

We welcome these recommendations and agree that building a more detailed AI/ML roadmap will be timely. This plan will identify activities that track a course towards the Met Office's stated ambitions of:

1. Maintain the UK's position as a world-leading modelling centre by remaining at the cutting edge of both physics-based and ML-based modelling.
2. Deliver world-leading weather and climate prediction data through an optimal blend of physics-based and ML-based modelling.
3. Position the Met Office as a centre of excellence by stimulating the national and international communities into improving the accuracy of, and trust in, ML weather models by establishing the criteria for design of models and frameworks for assessment and assurance of their quality.

As a part of this plan, we shall strengthen data infrastructure and data management approaches considering AI/ML developments. This will be a focus of the newly formed Data Curation and Data Engineering teams. In parallel the Data Delivery programme is considering data governance and metadata.

We thank MOSAC for these suggestions and will be considering dependencies on external partners. We agree that there will be a need to form a national conversation on UK capabilities in weather and climate.

Supercomputer

The new supercomputer's release has been delayed, so Gen 1 (a and b) and possibly Gen 2 hardware are not the latest. However, market changes might make CPU-based architecture more cost-effective. Extending Gen 1's life to overlap with Gen 2 is a good approach for effective hardware use and stability during transition. The Met Office staff deserve praise for keeping the Cray XC40 functional. Despite market uncertainty, AI/ML growth at the Met Office is certain. Adequate GPU resources are needed to support AI/ML in their workflow. Ensuring these capabilities for Gen 2 will help maintain progress and quality (SDE-R1 and SDE-R2).

We will be happy to provide specifications for Generation 1 systems with the papers for next year. We will unfortunately not be able to provide specifications for Generation 2 as we don't expect to have them in any detail by that point. We have work on-going at the moment to assess the cost effectiveness of GPUs as part of the work to specify Gen 2.

Momentum partnership: model and data assimilation

MOSAC is pleased with the progress with Open Sourcing Momentum, set to deliver this year. The BSD-derived license and Github platform will foster an external developer community. LFRIC's scientific performance and anticipated cost reductions are promising. MOSAC recommends revisiting LFRIC scalability testing soon (MM-R1). Despite progress, synchronizing JADA and LFRIC developments remain crucial (MM-R2). MOSAC encourages prioritizing this effort to reduce risks and optimize performance for the operational switchover.

We agree with this recommendation. It should be highlighted that assessment of the scalability of the dynamical core of LFRic (GungHo) has been explored (in collaboration with EPCC) using

resources available on Archer2 (https://arxiv.org/html/2409.15859v1). This shows good scaling. However, this doesn't capture interactions with the physics schemes, is constrained to a simple meteorological setup and doesn't include I/O. These aspects are critical to providing confidence in scalability of the system, so we will endeavour to carry out further scalability tests of the more complete system as soon as HPC resources become available.

JADA development is already using LFRic and will update to the latest science configurations of LFRic as and when they become available. For now, assessment of model forecast skill relies on the VAR system and will use JADA as soon as practicable. The appropriate links are in place between the NG-R2O, NG-PAO and GC6 projects to ensure that plans are coordinated.

MOSAC congratulates the Satellite and Surface Assimilation team on their progress with JEDI and their proactive approach to potential issues. They have exciting new regional developments planned. However, MOSAC considers developing two global data assimilation schemes inefficient. They urge Met Office management to decide on the operational schedule for data assimilation, considering the value of initial conditions and the practices of other centers (DA-R1). There are dependencies between the unstable LFRic version and the data assimilation system. Collaboration between DA and model teams is essential (DA-R2). MOSAC also recommends a collaborative approach for developing a training data strategy with the AI for National Capability team (DA-R3).

We thank MOSAC for their acknowledgement of the progress with JEDI and we welcome this recommendation as we agree that longer compute times for data assimilation will be beneficial to the overall NWP skill as demonstrated by ECMWF. We would be happy to report back at a future MOSAC the decision on computer resources for data assimilation and progress on the related strategy for the global data assimilation scheme.

We are working hard to ensure continued effective collaboration between DA and the model development / LFRic infrastructure teams. The need for a stable version of LFRic is key for progressing the development and tuning of JADA system. Until this is achieved, regular (fortnightly) meetings take place between DA and modelling teams to capture, understand and take action around any new developments that may have knock-on impacts.

We agree that our strategy for AI/ML training data must leverage in-house expertise from across the Met Office. Currently our DA experts are fully focused on the work required to develop and implement JADA. This is complex and high priority work which requires their full attention. They will, of course, engage with the AI work as and when they have the capacity.

Observation Exploitation

MOSAC was thrilled to see that JOPA's successful implementation is now speeding up the integration of new observations into operations. They congratulate the Met Office on their successes with Marine Gliders and global Mode-S and look forward to the introduction of new satellite data. Upgrading observation databases and data infrastructure is crucial, and MOSAC supports the development of a data management strategy to manage diverse data types from future satellite missions and crowdsourcing (OE-R1). They also recommend creating a comprehensive data strategy for seamless integration of new data initiatives and enhancing collaboration with Met Office Academic Partnership (MOAP) and UK Research Infrastructure (UKRI) to support academic research (OE-R2).

The “Future Observations Data Systems Roadmap" project (FODSR) has been set up to define a future architecture for observations data that is designed to meet the future requirements of all observations used. This project will align with existing Data Delivery projects that manage the architecture for data management for exploitation downstream of the modelling environment and inform the new AI/ML focussed efforts. We anticipate having clarity on direction by the end of 2025.

Physics Development

MOSAC commends the physics development team on the success of the new unified physics package. They have faced challenges applying new science, but now there's a clear plan for introducing advancements soon.

MOSAC supports combining machine learning with traditional methods for accurate atmospheric and land surface models. They recommend balancing resources for both approaches and ensuring hybrid AI-physical modeling doesn't hinder progress of unified physics R&D (PD-R1, PD-R2). Future includes exploring AI for surface models (PD-R3) and updating systems efficiently. MOSAC commends the innovative efforts and encourages continued development while addressing challenges in bringing new science to operational use.

We recognise the continued importance of physics-based modelling and thank MOSAC for this recommendation. We are committed to continued effort on physical parametrizations. There is research, both at the Met Office and amongst partners, emulating parts of the JULES land surface model. Reporting on them was omitted this year due to space considerations, but a presentation on land surface progress and plans may be appropriate next year.

K-scale

MOSAC commends the Met Office's advances in km-scale weather and climate models, highlighted by RAL3's validation at tropical and temperate latitudes. The unified physics for global and regional modelling at kilometre scale is crucial for future physical modelling. MOSAC supports the global-regional model hierarchy approach, ongoing K-scale research, and the contribution to DYAMOND3, encouraging further evaluation of downscaling, cloud organization, and machine learning emulators for improved predictions (KS-R1, KS-R2 and KS-R3).

We thank MOSAC for their very positive comments on the k-scale project.

Nowcasting extreme rainfall

MOSAC notes the progress of the PLUVIA framework in producing accurate precipitation analyses. It aids forecasters in extreme precipitation warnings. MOSAC advises prioritizing ML for better mesoscale nowcasting (NERE-R1). Extending PLUVIA Mesoanalysis with MTG-IRS, Mode-S, and MTG-FCI shows promise. Lightning data inclusion for thunderstorms is encouraged (NERE-R2). Testbeds are welcomed.

Recent work in the Met Office on using ML for aviation nowcasting applications has hugely increased our understanding of both the challenges and opportunities in this area. It may be beneficial to work with partners with more experience and expertise in Machine Learning and exploiting Met Office expertise in providing high quality data sets, such as our Mesoanalysis, that can be used for training, testing, and verifying ML nowcast models. We agree that lightning data should be included, and this is in our plans.

Ensembles in seasonal prediction

MOSAC is impressed by the Met Office's advances in seasonal forecasts. The Met Office is a world leader in seasonal forecasting. MOSAC commends the performance indicators, shown in scorecards, that help to measure system quality. MOSAC values deeper analysis of spread and error relationships and intriguing insights on extreme hot conditions (ESP-R1). Seasonal forecast applications are crucial for the Met Office's mission. MOSAC suggests that some further development relates to the customer needs (ESP-R2).

As we extract further skill from the seasonal predictions, we agree that exploring customer requirements is crucial for the Met Office. We are engaging with the Department for Energy Security and Net Zero (DESNZ) as they already use our forecasts for energy resilience planning and we are investigating how they can extract more benefit from both our seasonal forecasts and the associated ensemble analysis of extreme events. Other users include other National Met Services who take data feeds and the Copernicus Climate Change Service who also receive real time data feeds. We also have a dedicated International Sub-Seasonal to Seasonal Outreach team in the STEP area of Programmes, which undertakes capacity building and outreach activities on seasonal forecasting and its applications, predominantly through the WMO Regional Climate Outlook Forums (RCOFs) and associated user-engagement forums.

Forecasting Services

Hazards to Decision-Making

The National Severe Weather Warning Service (NSWWS) risk matrix approach to create impact-based warnings is recognized as the best practice globally. MOSAC praises the Met Office for its strong relationship with the resilience community and for ensuring partners understand the risk matrix and are comfortable with probabilistic concepts. Public surveys show NSWWS is effective, with 95% of respondents acting on the warning for Storm Darragh. However, yellow warnings can be problematic due to various combinations of likelihood and impact (HDM-R1). Social science research is recommended to improve communication and public trust in yellow warnings (HDM-R2 and HDM-R3). The Met Office is encouraged to invest in its in-house social science capabilities (HDM-R4).

We are pleased that MOSAC acknowledge the critical roles of social science and risk communication in realizing the value of the NSWWS and the science which underpins it. Finding the optimum ways to communicate different risks – graphically, textually, numerically etc. - in order to inform user decision-making and to trigger the appropriate response is a key component of the Common Warnings Framework being developed by the Met Office and the UK's flood agencies. We agree that recent events suggest a more 'operational' use of social science may be required at times to help preserve the trust of the public and other stakeholders.

Seamless extremes

MOSAC commends the Met Office for its leadership in ensemble forecasting. The new ESA and Clustering tools provide valuable insights, and their integration is encouraged (SE-R1). Cross-domain applications promote collaboration and break down barriers. AI-assisted research aids in understanding extreme events for better policymaking (SE-R2). Diverse perspectives are crucial for effective risk management, as highlighted by examples like the Valencia flood. MOSAC urges reflection on long-term risks and developing workflows for extreme events (SE-R3).

Thank you for this encouragement. We intend to continue existing activities and partnerships to support this recommendation and will look to identify further opportunities moving forward.

Forecast Accuracy

MOSAC commends the Met Office for strategically improving its model verification and evaluation processes, crucial for assessing performance and building user trust. The MO aims to include user value-oriented metrics and seeks opportunities to measure forecast quality in terms of user value, involving subject matter experts (FA-R1). The release of the IMPROVER system has enhanced forecast accuracy. MOSAC supports model upgrades for better realism and reliability, even with slight NWP score declines. With AI/ML models rising, MOSAC endorses new evaluation approaches and urges cooperation with WMO experts and tech companies to develop and apply comprehensive AI/ML model verification (FA-R2, FA-R3 and AI-R2).

We want to be open with private companies about standards/ metrics that they might want to use to create good forecasts and have established some interactions with the tech industry to support this. We will take the above recommendation into account as we continue to collaborate with private companies and will be vocal and open about what good accuracy looks like on our public-facing channels. We will continue advocating for high standards for all and encouraging AI based forecasts to be introduced to the market responsibly.

Space Weather

MOSAC discussed space weather for the first time, focusing on the Space Weather Research (SWR) team, which aims to enhance the Met Office Space Weather Operations Centre (MOSWOC) products. While MOSWOC's primary role is defined by the UK National Risk Register, future user communities in government and industry could emerge. A high-impact event, like a G5 geomagnetic storm, might increase demand for urgent and critical guidance. The SWIMMR program has been successful, providing components for a complete forecasting chain, but challenges remain in integrating these components (SW-R1). MOSAC recommends maintaining the SWR community and leveraging Met Office expertise for deploying new instruments and enhancing forecast products (SW-R2 and SW-R3).

We recognize these challenges and SWIMMR follow-on support contracts have been put in place with the lead institutes for the SWIMMR modelling projects. This will ensure that the SWR team has ongoing support for the integration, and that these models can be successfully integrated by the September 2026 target date.

Concluding Remarks

The Met Office is deploying new supercomputers, a monumental task that deserves recognition. These advancements enable strategic initiatives like parallel suite releases and enhanced climate modelling. Artificial intelligence and machine learning are revolutionizing meteorology and climate studies. To capitalize on this, the Met Office has prioritized resources, affecting observational research staff and community contributions. MOSAC seeks clarity on filling research observation gaps. The programs focused on artificial intelligence for numerical weather prediction and climate show promising results, but a clear strategy for AI and data is needed.

The progress in research and development for model and data assimilation to deliver seamless services, from high-impact nowcasting to seasonal predictions, is remarkable. Maintaining national and international partnerships is crucial to sustaining this momentum. MOSAC commends the Met Office's strong relationship with the resilience community. While the National Severe Weather Warning Service is globally recognized, social science research can enhance communication and build public trust.

Heartfelt thanks to the technical and administrative teams for their outstanding organization and efficient management of this meeting.

MOSAC deeply appreciates the Met Office leadership, speakers, and poster presenters for their outstanding contributions. The meeting was intellectually stimulating and challenging, yet the open and collaborative spirit of all participants made it a truly enjoyable and fulfilling experience. Thank you to everyone involved for making this meeting a success.

Gilbert Brunet (Chair) on behalf of the Met Office Scientific Advisory Committee: Natacha Bernier, Andy Brown, George Craig, Sarah Dance, Beth Ebert, Wilco Hazeleger, Owain Kenway and Christine Lac.